Relative Merits. Deficient hold-down capacity of precast units usually will occur when one unit or a part of one unit is required to resist a significant share of the seismic load. If the wall has sufficient bending and shear capacity, then increasing the hold-down capacity using Technique 1 is usually the most cost-effective. When a wall is comprised of a number of solid (i.e., no significant openings) precast panels, the overturning forces generally will be minimal provided there is adequate vertical shear capacity in the connection between the edges of adjacent panels. In this case, the connections must be checked and, if necessary, strengthened as described in Sec. 3.2.2.

Technique 2 usually is a viable approach only if it is being considered to correct other component deficiencies. When excessive uplift forces are due to inadequate vertical shear capacity in the vertical connections between adjacent precast units, strengthening of those connections (see Sec. 3.2.2) will reduce the uplift forces.

3.8.4 CONNECTION OF BRACED FRAMES

3.8.4.1 Deficiencies

The principal deficiencies of the connections of steel braced frames to the foundation are:

- Inadequate shear capacity and
- Inadequate uplift resistance.

3.8.4.2 Strengthening Techniques for Shear Capacity

Techniques. Deficient shear capacity of the connections of steel braced frames to the foundations can be improved by:

1. Increasing the capacity by providing new steel members welded to the braced frame base plates and anchored to the slab or foundation with drilled and grouted anchor bolts.
2. Reducing the shear loads by providing supplemental steel braced frames as discussed in Sec. 3.4.

Relative Merits. The first alternative generally will be the most cost-effective provided the existing slab or foundation can adequately resist the prescribed shear. Steel collectors welded to the existing steel base plates may be necessary to distribute the shear forces into the slab or foundation. If the existing foundation requires strengthening to provide adequate shear capacity, determining the most cost-effective alternative requires comparing the effort necessary to construct a reinforced concrete foundation to the effort and disruption of functional space required to install supplementary shear walls and their associated foundations and collectors.

3.8.4.3 Strengthening Techniques for Uplift Resistance

Techniques. Deficient uplift resistance capacity of the connections of steel braced frames to the foundations can be improved by:

1. Increasing the capacity by providing new steel members welded to the base plate and anchored to the existing foundation.
2. Reducing the uplift loads by providing supplemental steel braced frames as discussed in Sec. 3.4.

Relative Merits. Inadequate uplift resistance capacity of a steel braced frame seldom results just because of deficient connection to the foundation but is typically a concern reflecting the uplift capacity of the foundation itself. If the foundation is the concern, the techniques discussed in Sec. 3.6 can be considered to correct the problem. If, in fact, the deficiency is the connection, Technique 1 (providing new connecting members) will be the most economical.

3.8.5 CONNECTIONS OF STEEL MOMENT FRAMES

3.8.5.1 Deficiencies

The principal deficiencies of the connection of a moment frame column to the foundation are:

- Inadequate shear capacity,
- Inadequate flexural capacity, and
- Inadequate uplift capacity.

3.8.5.2 Strengthening Techniques for Shear, Flexural, and Uplift Capacity

Techniques. The techniques for strengthening steel moment frame column base connections to improve shear and flexural capacity also will likely improve the uplift capacity. For this reason a combination of the following alternatives may be utilized to correct a deficient column base connection:

1. Increasing the shear capacity by providing steel shear lugs welded to the base plate and embedded in the foundation.
2. Increasing the shear and tensile capacity by installing additional anchor bolts into the foundation.
3. Increasing the shear capacity by embedding the column in a reinforced concrete pedestal that is bonded or embedded into the existing slab or foundation.

Relative Merits. While it may be possible to strengthen the column and to stiffen the base plate against local bending, it usually is not practical to increase the size of the base plate or the number of anchor bolts without removal and replacement of the base plate. The horizontal column shears may be transferred to the column footing by shear lugs between the base plate and the footing and/or shear in the anchor bolts (Technique 1) and to the ground by passive pressure against the side of the footing. If the column base connection is embedded in a monolithic concrete slab, the slab may be considered for distribution of the shear to the ground by means of any additional existing footings that are connected to the slab. If the column is not embedded in the slab, the same affect can be achieved by adding a concrete pedestal (Technique 3). The interference of this pedestal with the function and operations of the area is an obvious drawback.

3.9 ADDING A NEW SUPPLEMENTAL SYSTEM

Consideration of a new lateral-force-resisting system may be a cost-effective alternative for some seismically deficient structures. The extent of overstress of an existing structure may be such that strengthening the existing elements is very costly and adding supplemental vertical-resisting elements (as discussed in Sec. 3.4) becomes so extensive that an entirely new supplemental lateral-force-resisting system is the best way to resist the prescribed forces.

Adding a new supplemental lateral-force-resisting system also may be the most cost-effective alternative when preservation of architectural features is of utmost importance, (e.g., in a historical monument).

3.9.1 SUPPLEMENTAL BRACED FRAME SYSTEM

Moment frame buildings that have insufficient lateral resistance can be converted to a braced frame system. This retrofit can add substantial lateral capacity with a minimum of additional weight. Changing a moment frame to a braced frame also will significantly reduce drifts and, hence, architectural damage. Buildings with weak shear walls (either wood or unreinforced masonry) also have been strengthened using steel braced frames. Figure 3.9.1 shows the central storeroom at Lawrence Berkeley Laboratory in Berkeley, California, in which an X-braced steel frame was used to strengthen the structure. The principal disadvantages of adding braced frames are the potential change in the architectural character and the potential obstruction of accessways and window views. Additionally, the conversion of moment frames to braced frames may increase demand on and consequently necessitate an upgrade of the existing foundation.

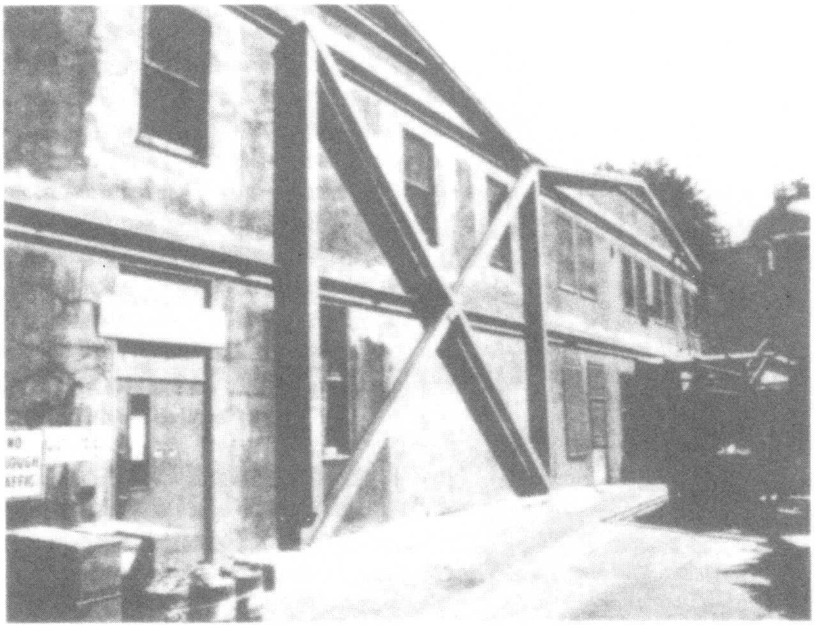

FIGURE 3.9.1 Seismic strengthening using a supplemental braced frame system.

3.9.2 NEW SHEAR WALL SYSTEM

The addition of a new reinforced concrete shear wall system to an unreinforced masonry structure can meet the requirements for a seismic upgrade in certain cases. Margaret Jacks Hall on the Stanford University campus (Figure 3.9.2a) is an example of a building for which preservation of the architectural character was a prime consideration. The existing unreinforced masonry was determined through testing to provide little lateral capacity. The exterior sandstone masonry was retained, and the interior was gutted. New concrete walls were pneumatically applied to the old masonry, and new floors, columns, and a roof were constructed. Another example of the need to preserve the historically significant architectural character of a building is the California State Capitol (Figure 3.9.2b). In essence, the existing stone facade was retained while new lateral- and (in large part) vertical-force-resisting systems were constructed.